

Aspects of HET Group's Research on New Physics: from Collisions to the Cosmos

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DOE Review of HEP Theory

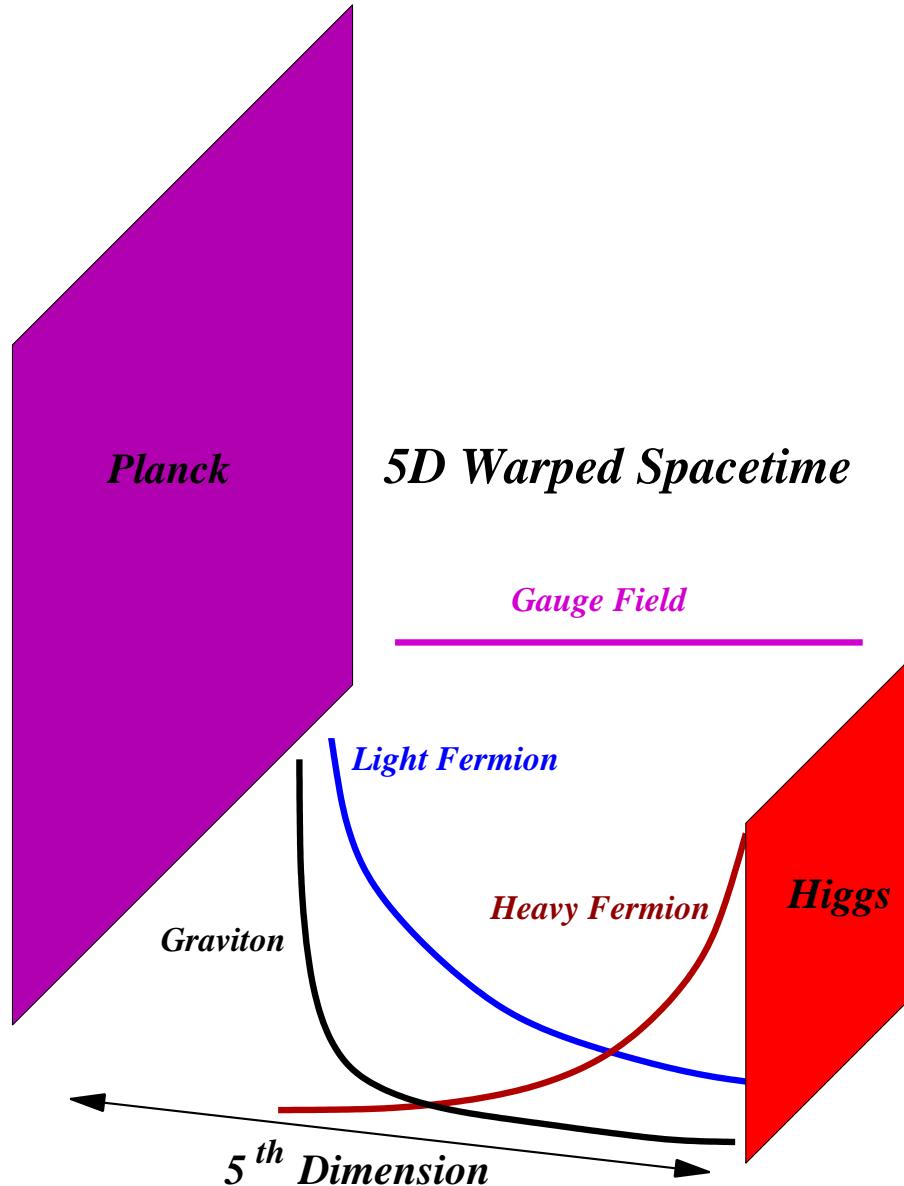
July 26, 2011

Selected works by the HET group members

- **Warped 5D phenomenology (strong dynamics):**
 - Little Randall-Sundrum models, signals.
- **$U(1)'$ models:**
 - Supersymmetric theories.
 - Neutrino physics.
- **Particle cosmology and astrophysics:**
 - Baryogenesis.
 - Dark Matter.

Research covers a wide variety of questions.

Warped 5D Phenomenology



- **Randall-Sundrum (RS) model** L. Randall, R. Sundrum, 1999

- Address hierarchy: $M_W \sim 10^2$ GeV, $M_{\text{Pl}} \sim 10^{19}$ GeV.
- Slice of AdS_5 , curvature $k \sim M_{\text{Pl}}$, size $L = \pi r$: $M_W \sim e^{-k\pi r} k$, $k\pi r \approx 35$.
- 5D fermions → natural framework for flavor.
- Signals:
 - Kaluza-Klein (KK) modes.
 - Higgs-like radion ϕ , coupling Λ_ϕ^{-1} ($\sim \text{TeV}^{-1}$).

W. Goldberger, M. Wise, 1999

- Dual to weak-scale strong dynamics.*

* Based on AdS/CFT (J. Maldacena, 1997)

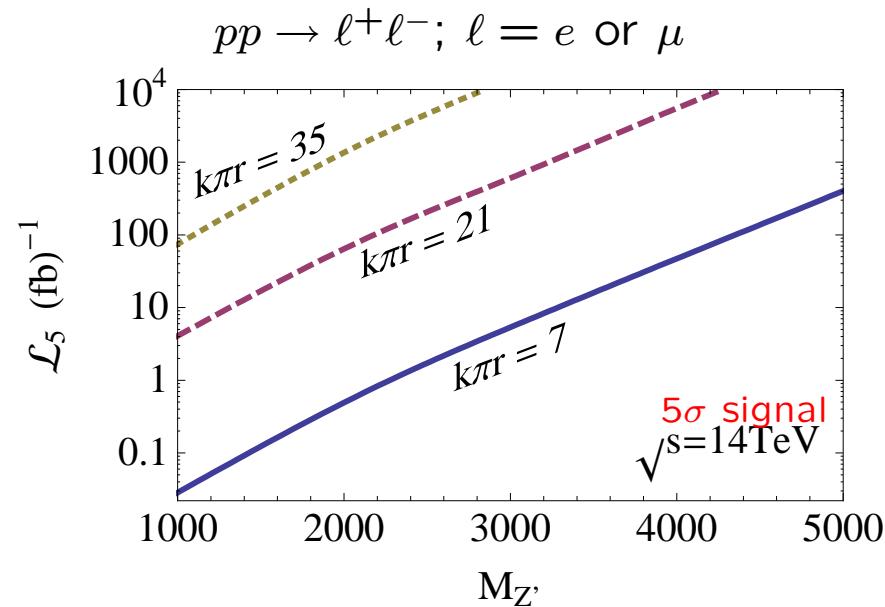
- **Little RS models of flavor**

H. Davoudiasl (BNL), G. Perez (SBU), A. Soni (BNL), 2008

- RS truncation: UV scale $k \gtrsim 1000$ TeV (flavor); $k\pi r \gtrsim 7$.
- Certain unwanted effects suppressed by truncation.
- Some clean signals enhanced.
- TeV data: Does UV regime (dual conformal dynamics) extend to M_{Pl} ?

- **LRS Z' (neutral vector KK) di-lepton signals at the LHC**

H. Davoudiasl, S. Gopalakrishna (former postdoc), A. Soni, Phys.Lett. B686 (2010)



- Enhanced di-photon signal for the LRS radion scalar

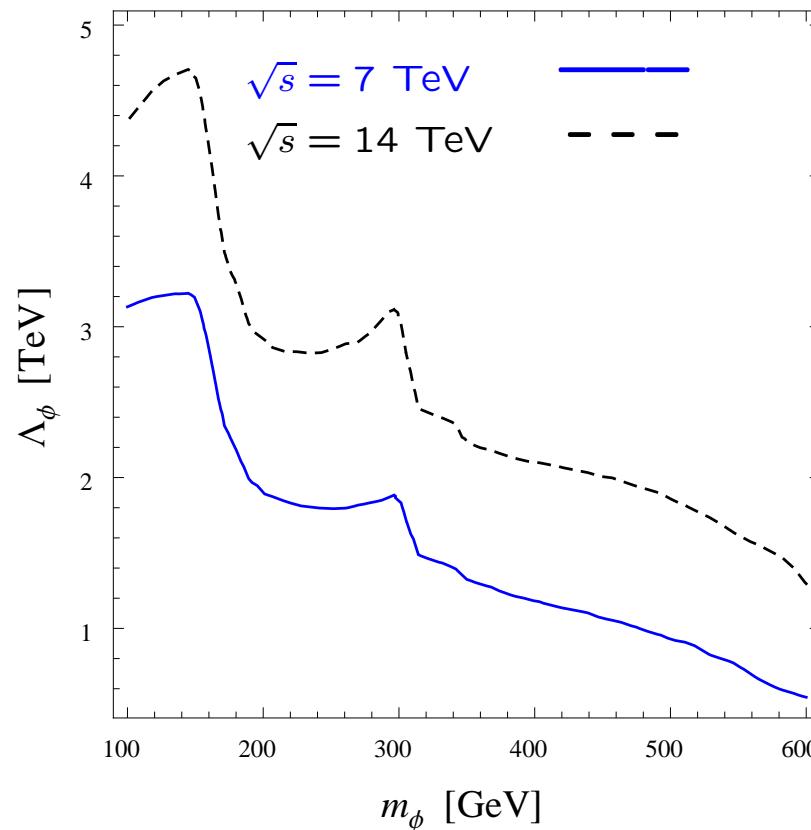
H. Davoudiasl, T. McElmurry (postdoc), A. Soni, Phys.Rev. D82 (2010) 115028

- Enhanced radion coupling to gg and $\gamma\gamma$ vis à vis RS.

- For masses $\sim 100 - 150$ GeV:

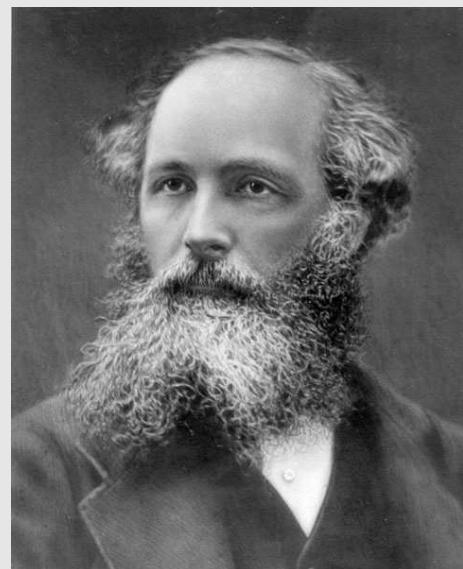
LRS ($k\pi r = 7$): $\text{Br}(\gamma\gamma) \sim 10^{-2}$; RS ($k\pi r = 35$), SM Higgs: $\text{Br}(\gamma\gamma) \sim 10^{-3}$.

- LHC 5σ reach, with 1 fb^{-1} :



$U(1)'$ Models

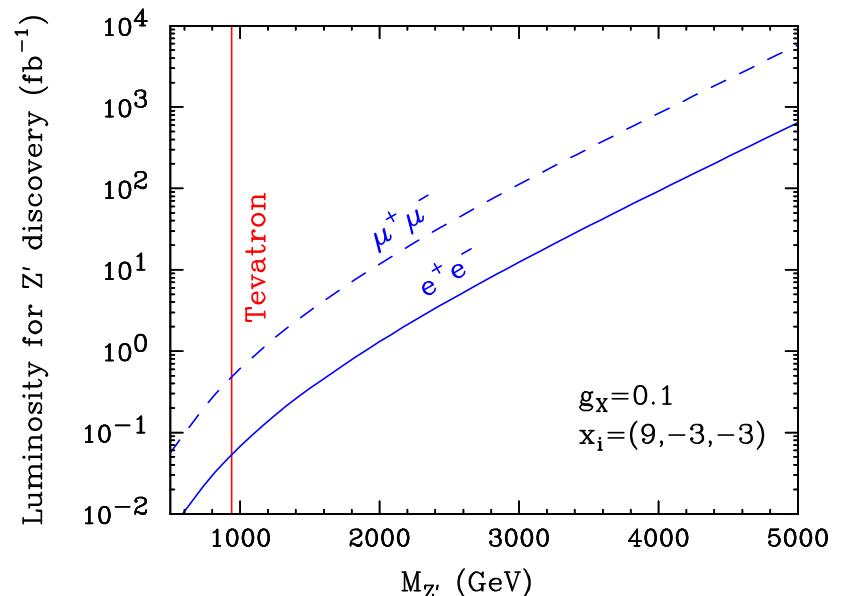
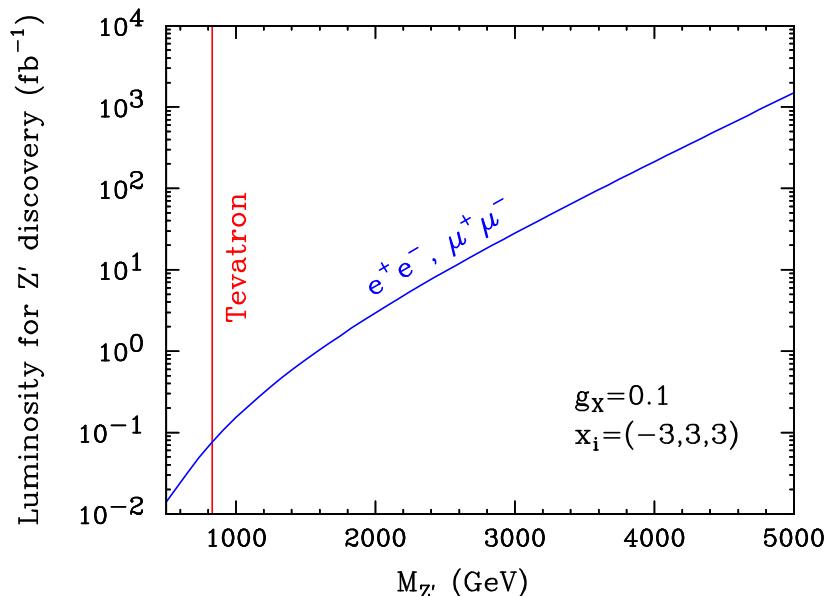
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- **Gauged $B - x_i L_i$** $x_e + x_\mu + x_\tau = 3$ ($x_i \neq 1$).

H.-S. Lee (postdoc), E. Ma, Phys.Lett. B688 (2010)

- Alternative to $B - L$ as a gauge origin of R-parity for supersymmetric theories.
- LSP DM.
- Neutrino masses and mixings.
- \mathbb{Z}_3 (baryon triality) \rightarrow absolute proton stability.
- LHC reach ($\sqrt{s} = 14$ TeV)



- New long-range interactions and neutrino oscillations

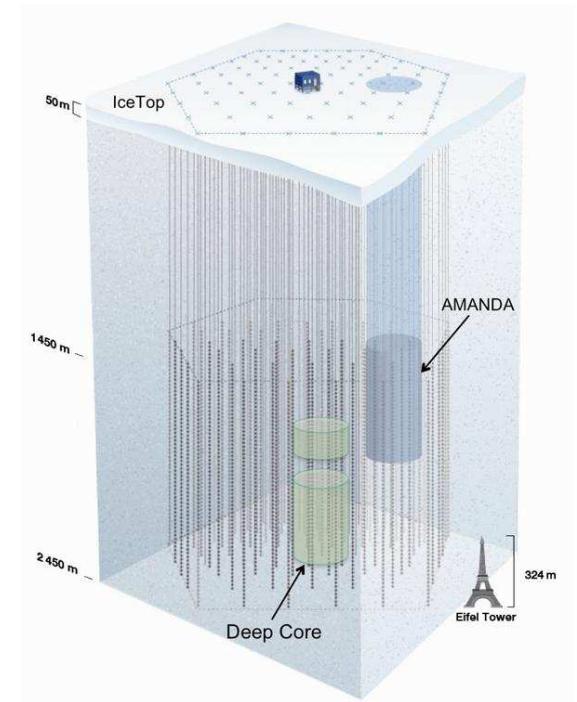
H. Davoudiasl, H.-S. Lee, W. Marciano (BNL), arXiv:1102.5352 [hep-ph] (to be published in PRD)

- Initial motivation: MINOS results for ν_μ and $\bar{\nu}_\mu$ disappearance

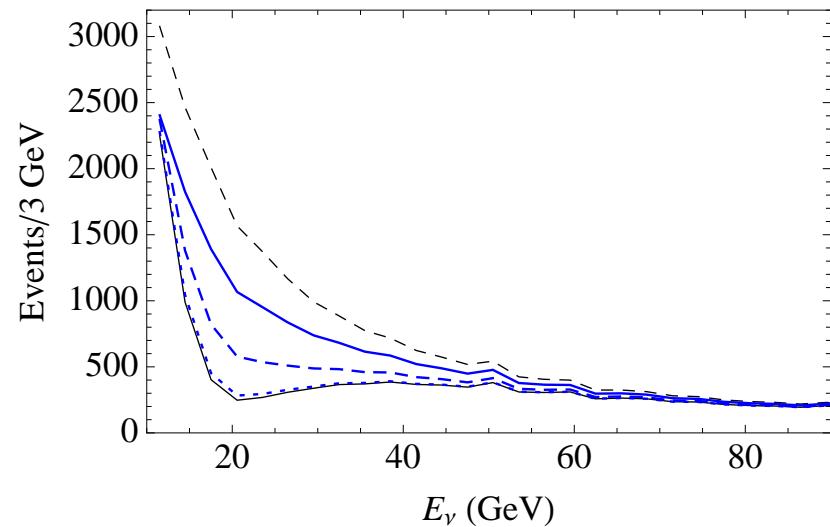
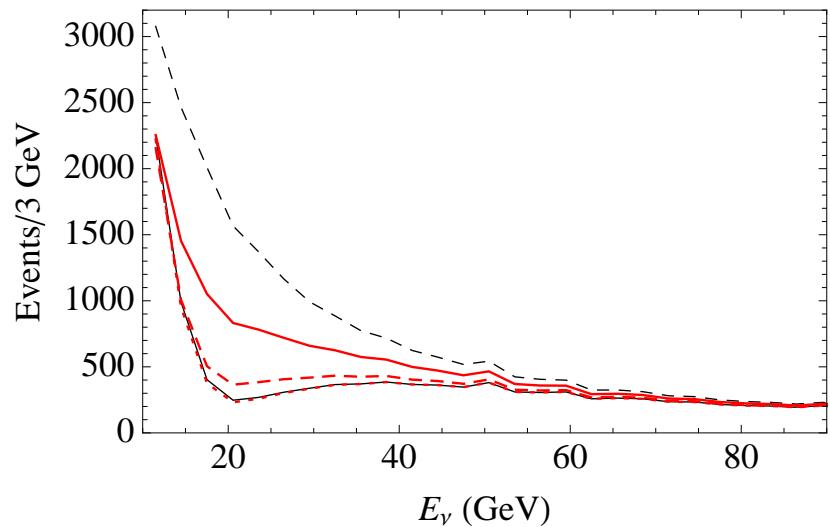
$$|\Delta m_{23}^2| = 2.35_{-0.08}^{+0.11} \times 10^{-3} \text{ eV}^2; \sin^2(2\theta_{23}) = 1.00 \quad \text{MINOS Collaboration, 2011}$$

$$|\Delta \bar{m}_{23}^2| = 3.36_{-0.40}^{+0.45} \times 10^{-3} \text{ eV}^2; \sin^2(2\bar{\theta}_{23}) = 0.86 \pm 0.11$$

- Gauge $(B - L) + (L_\mu - L_\tau)$, $m_{Z'} \sim 10^{-18} \text{ eV} (\sim 1/\text{AU})$.
 - Long-range $U(1)'$ potential ($1/R$) from *neutrons* in the Sun and Earth.
 - Opposite signs for ν and $\bar{\nu}$.
 - MINOS results suggest:
- $$\Delta m_{23}^2 = 2.4 \times 10^{-3} \text{ eV}^2; \sin^2(2\theta_{23}) = 0.89; \alpha' = 1.0 \times 10^{-52}.$$
- Test: e.g. DeepCore array at IceCube (operational).
 - Large sample ($\sim 10^5/\text{yr}$) of atmospheric neutrinos.



- Top to bottom: no oscillation, $\alpha' = 1.0, 0.5, 0.1, 0 \times 10^{-52}$, $\sin^2(2\theta_{23}) = 0.9$
- $\Delta m_{23}^2 = \pm 2.4 \times 10^{-3} \text{ eV}^2$ (left/right).



- Possibly test solar origin:
 - Sun-Earth distance variations.

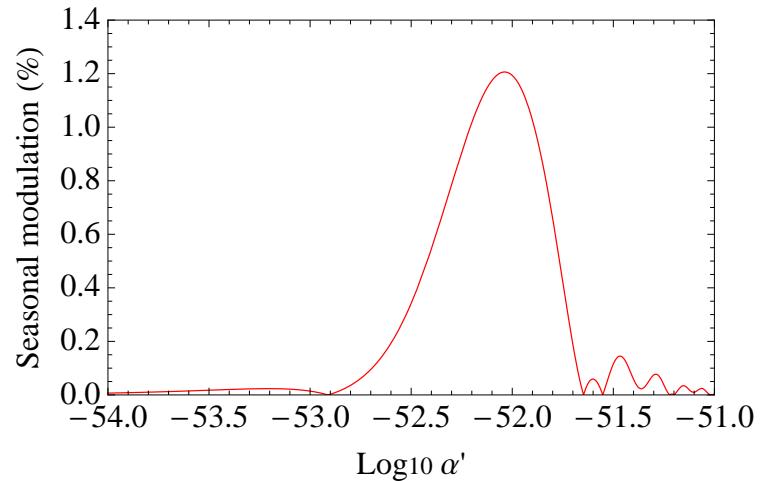
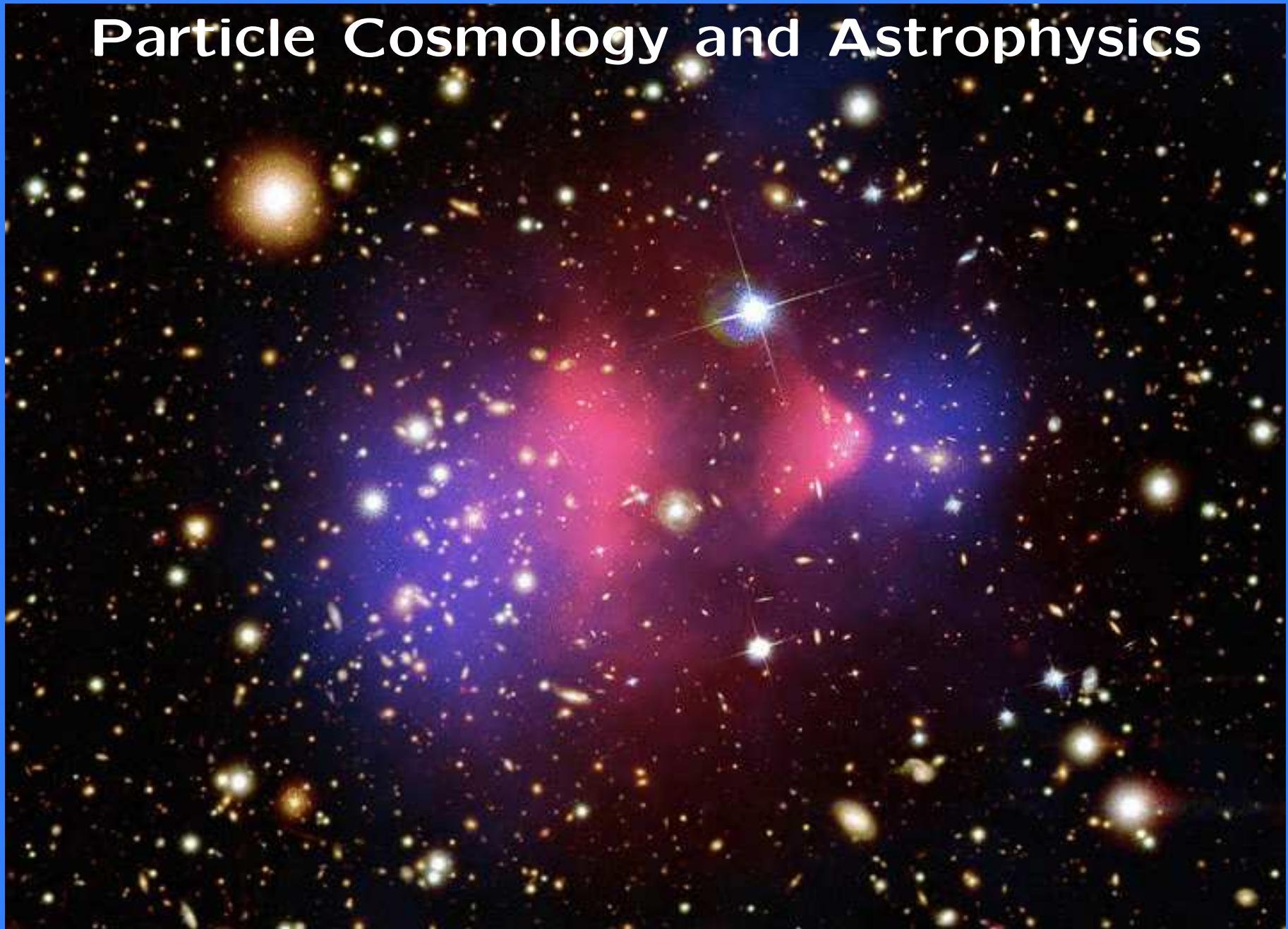


Figure: 60 days before and after each apsis, $15 \text{ GeV} < E_\nu < 30 \text{ GeV}$.

Particle Cosmology and Astrophysics

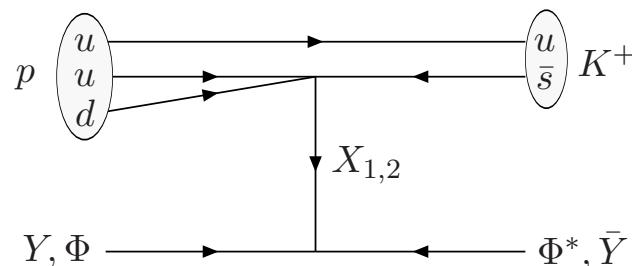


- **Hylogenesis: a unified origin for visible and dark matter**

H. Davoudiasl, D. Morrissey, K. Sigurdson, S. Tulin, Phys.Rev.Lett. 105 (2010) 211304

Press: New Scientist Magazine, Physicsworld.com, Wired.com, ...

- Motivation: $\Omega_{DM} \approx 5\Omega_B$ suggests common origin (asymmetry).
- Non-thermal X_1, \bar{X}_1 population (inflation), generalized baryon number.
- $X_1 \rightarrow udd, X_1 \rightarrow \bar{Y}\Phi^*$, CP violation.
- CPT: equal and opposite baryon asymmetries in quarks and (Y, Φ) .
- **Striking signature: Induced Nucleon Decay (IND).**
 - IND: mimics standard $N \rightarrow \nu + \text{meson}$, different kinematics; $\tau_{\text{eff}}^N \gtrsim 10^{32} \text{ yr}$.
 - DM detection at Super-Kamiokande, future nucleon decay experiments.

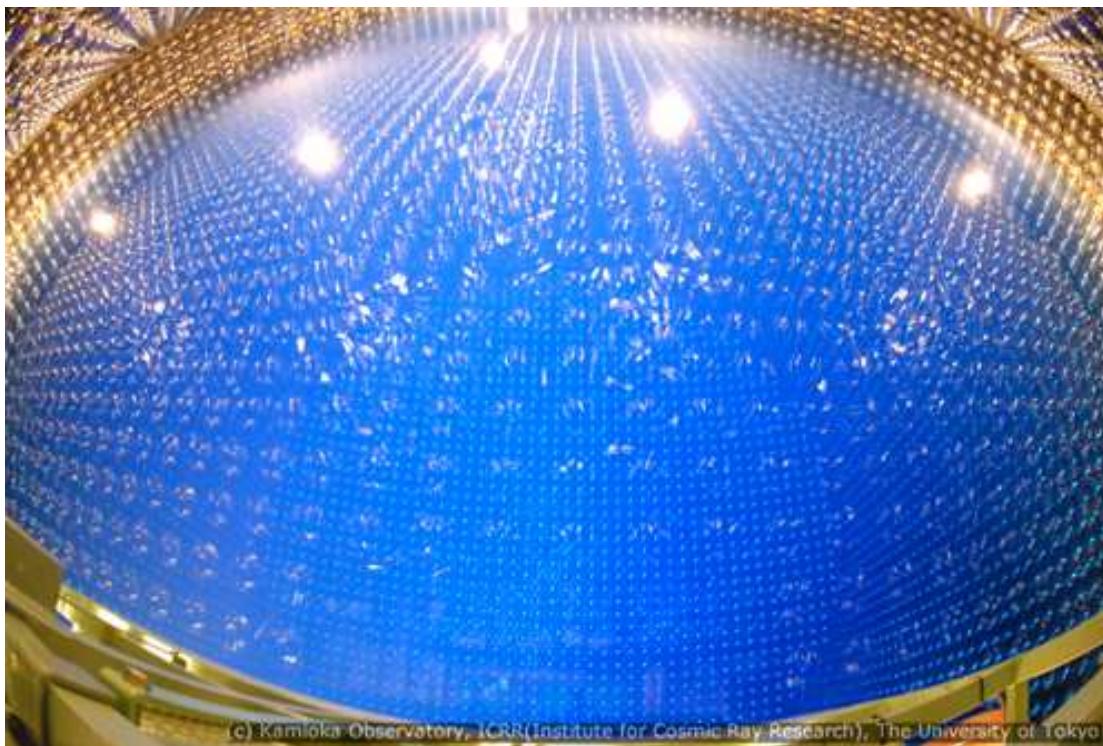


| Decay mode | p_M^{SND} (MeV) | p_M^{IND} (MeV) |
|----------------------|--------------------------|--------------------------|
| $N \rightarrow \pi$ | 460 | 800 - 1400 |
| $N \rightarrow K$ | 340 | 680 - 1360 |
| $N \rightarrow \eta$ | 310 | 650 - 1340 |

- **Hidden MeV-scale dark matter in neutrino detectors**

J. Kile (former postdoc), A. Soni, Phys.Rev. D80 (2009) 115017

- Dark matter: singlet fermion f .
- Inelastic scattering $\bar{f}p \rightarrow ne^+$ in neutrino detectors.
- Dim-6 operator $(\bar{\ell}_r \gamma_\mu f)(\bar{u}_R \gamma^\mu d_R)/\Lambda^2$: interesting rates for $m_f \lesssim m_\pi$.
- Super Kamiokande can probe $\Lambda \lesssim 100$ TeV.



(c) Kamioka Observatory, ICRR (Institute for Cosmic Ray Research), The University of Tokyo

Summary

Research in the HET group (also Sally's presentation):

- *Wide range of topics in physics beyond SM.*
 - Outstanding questions, from the **Tera scale** to the **Hubble scale**.
- *Relevant to the US worldwide experimental involvement.*
 - LHC and Tevatron physics
 - Flavor and intensity frontier
 - Neutrino oscillations
 - Dark matter searches
 - . . .